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A Digitized Biotic Community Map for Plotting and Comparing North American Plant and Animal Distributions

David E. Brown, Thomas C. Brennan and Peter J. Unmack 1

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Editor: Leslie R. Landrum
P. O. Box 874501
School of Life Sciences
Arizona State University
Tempe, AZ 85287-4501
(les.landrum@asu.edu)

Production Editor: S.T. Bates
School of Life Sciences
Arizona State University
PO Box 874601
Tempe AZ 85287-4601
(scott.bates@asu.edu)

Canotia publishes botanical and mycological papers related to Arizona. These may include contributions to the Vascular Plants of Arizona project, checklists, local floras, new records for Arizona and ecological studies. All manuscripts are peer-reviewed by specialists. Acceptance for publication will be at the discretion of the editor. At least 30 printed copies of each issue are distributed to libraries in the United States, Europe, and Latin America. Anyone may download copies free of charge at http://lifesciences.asu.edu/herbarium/canotia.html.

Canotia is named for *Canotia holacantha* Torr. (Celastraceae), a spiny shrub or small tree nearly endemic to Arizona.

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A DIGITIZED BIOTIC COMMUNITY MAP FOR PLOTTING AND COMPARING NORTH AMERICAN PLANT AND ANIMAL DISTRIBUTIONS

David E. Brown* and Thomas C. Brennan
Arizona State University
School of Life Sciences,
P.O. Box 874501
Tempe, AZ 85287-4501, USA

Peter J. Unmack
Integrative Biology
401 WIDB,
Brigham Young University
Provo, UT 84602, USA

*Corresponding author: D.E. Brown; e-mail: debrown@imap3.asu.edu

ABSTRACT

An ecologically based classification system, when accompanied by digitized biotic community maps, has been shown to be useful for plotting and assessing plant and animal affinities in the American Southwest and northwestern Mexico. Because plant distributions are closely tied to climatic and environmental parameters, biotic community maps can be especially informative when delineating and describing vegetative communities and plant species distributions. We have therefore expanded the classification system and prepared a digitized, ecologically based color map of North America's biotic communities to assess plant distributions on continental as well as regional scales.

Key Words: ArcMap, biogeography, biotic community, GIS, habitat map, plant distribution, vegetation, vegetation map.

A DIGITIZED BIOTIC COMMUNITY MAP

Biotic communities are regional plant formations that evolved within particular climatic patterns, and are characterized by a particular suite of plant and animal species (Brown et al. 1998). As such, biotic communities are useful in describing the habitat affinities of particular plant and animal taxa, and determining the biogeographic distributions of species (e.g., Brown 1994, Brown et al.1998). The resulting maps are also useful in designing sampling strategies and assessing populations for particular species.

Incorporating the work and terminology of a broad range of ecologists and biogeographers, we developed a hierarchical classification formulated on the limiting effects of moisture and temperature minima on the structure and composition of vegetation. This effort eventually resulted in a digitized, computer-compatible classification system for the biotic communities of Arizona, the "Southwest," and North America (Lowe & Brown 1973, Brown & Lowe 1974a, Brown & Lowe 1974b,

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Brown et al. 1979, Brown 1980, Brown 1982, Brown 1994, Brown et al. 1998). Attendant with these efforts was a series of maps delineating vegetation as the mapable reality of biotic community boundaries (Brown 1973 - Fig. 1, Brown & Lowe 1982 & 1994 - Fig. 2, Reichenbacher et al. 1998).

These biotic community maps have proven useful to anthropologists (e.g., Floyd et al. 2003), archeologists (e.g., Huckell 1996), climatologists (e.g., Davidowitz 2002), ecologists (e.g., Lange et al. 2000), and other scientists interested in the assessment, delineation and stratification of biotic resources along with the identification of natural areas (e.g., Martin 1979). The maps and classification system have therefore been used by the Rangelands Group of the Environmental Protection Agency's Environmental Monitoring and Assessment Program, the Arizona and New Mexico Game and Fish Departments, and other agencies charged with biotic resource inventory (e.g., Anonymous 2006). Both the classification and maps have been used by PhotoAssist, Inc. to design the biome map series of stamps issued by the U. S. Post Office, and assisted the National Geographic Society's mapping division in delineating Sonoran Desert community boundaries. Moreover, the biogeographical validity of the hierarchy's various categories are statistically testable through the use of climatic data and the "system" has been used to digitally plot numerous plant and animal distributions. A recent example of the former is the distribution maps promulgated by Brennan and Holycross (2005, 2006) and the Southwest Environmental Information Network maintained by the Vascular Plant Herbarium at Arizona State University (http://seinet.asu.edu/).

A recent "Google Scholar Search" of the scientific literature listed more than one-thousand citations for either the biotic community classification system or an accompanying map. Citations accompanied articles pertaining to general biogeographical comparisons (e.g., Floyd et al. 2000, Paysen et al. 2000, DeSilva & Medelin 2002, Coblentz & Riitters 2004, Flesch & Hahn 2005), vegetation communities and plant occurrences (e.g., Roth 2004, Laughlin et al. 2005), archeological sites (e.g., Cannon 2000), and regional climate studies (e.g., Engelthaler et al. 1999, Enscore et al. 2002, Smith & Farrell 2005) in addition to plant and animal distributions (e.g., Lanning et al. 1990, Diem 2003, Barton 2005).

Articles using these classifications and maps to describe plant distributions were noted in such publications as *American Journal of Botany* (e.g., Maschinski et al. 2004), *Annals of the Association of American Geographers* (e.g., Diem 2003), *Annals of Botany* (e.g., Martínez & López-Portrillo 2003a), *Arctic, Antarctic, and Alpine Research* (e.g., Moore & Huffman 2004), *Biodiversity and Conservation* (e.g., Richter & Stromberg 2005), *Botanical Journal of the Linnean Society* (e.g., Romero et al. 2000), *Canadian Journal of Botany* (e.g., Stutz et al. 2000), *Conservation Biology* (e.g., Floyd et al. 2003), *Freshwater Biology* (e.g., Stromberg 2001), *Ecology* (e.g., Weltzin & McPherson 2000), *Ecological Applications* (e.g., Floyd et al. 2000), *Ecological Monographs* (e.g., Weltzin & McPherson 1999), *Environmental Toxicology and Chemistry* (e.g., Gardea-Torresdey et al. 2001), *Global Ecology and Biogeography* (e.g., Drezner et al. 2001), *International Journal Plant Science* (e.g., Lange et al. 2000), *Journal of Arid Environments* (e.g., Kennedy et al. 2002), *Journal Arizona-Nevada Academy Science* (e.g., Abella 2004), *Journal of Biogeography*

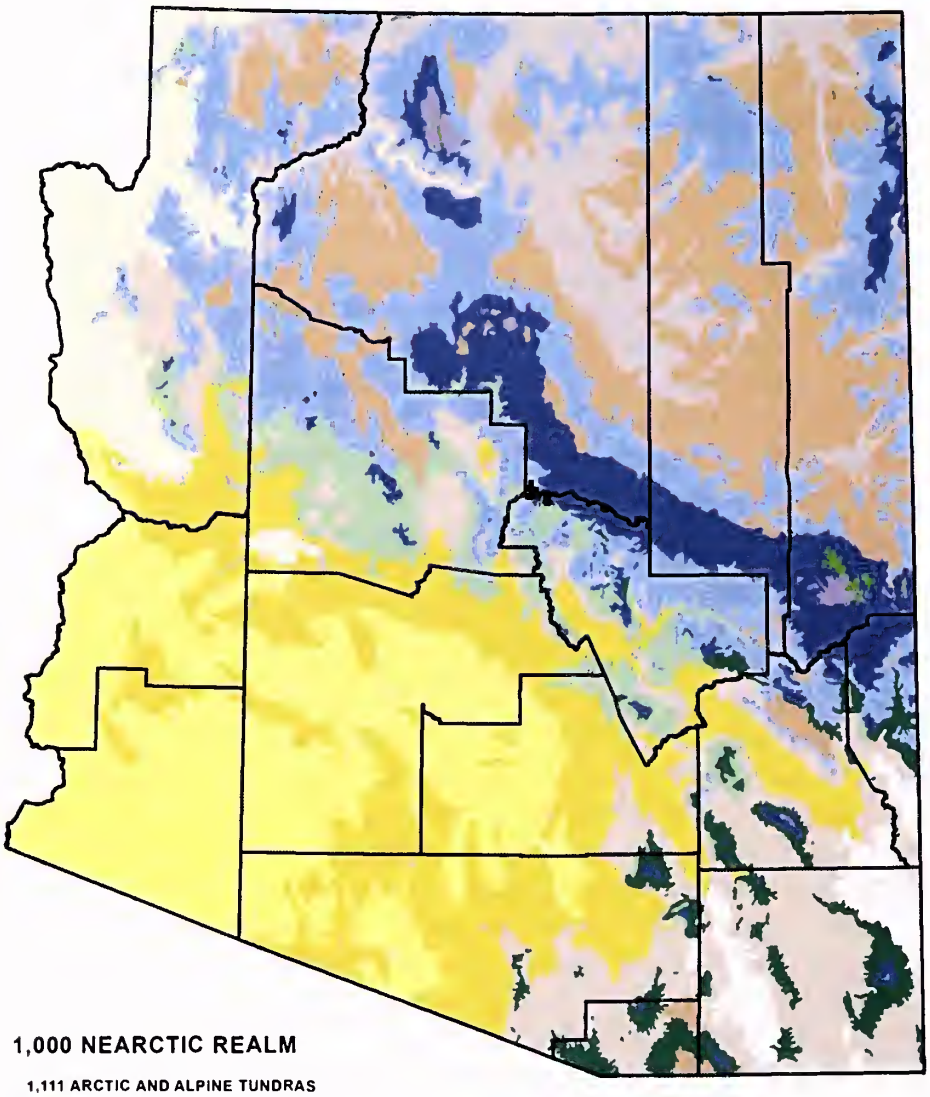
(e.g., Adams & Kolb 2005), *Journal of Ecology* (e.g., Smith et al. 2000), *Journal of Environmental Management* (e.g., Miller et al. 2003), *Journal of Vegetation Science* (e.g., Martínez & López-Portillo 2003b), *Plant Ecology* (e.g., Martinez-Yrizar et al. 1999), *Restoration Ecology* (e.g., Abella & Covington 2004), *Southwestern Naturalist* (e.g., Scott 2004, Peinado et al. 2005), and *Vegetatio* (e.g., White & Vankat 1993).

In an effort to expand the usefulness of the biotic classification system we prepared a digitized biotic communities map for North America (Figs. 3 & 4) compatible with those previously published for Arizona and the Southwest (Figs. 1 & 2). For a base chart, using the GIS software ArcInfo, we enhanced the 1:10,000,000 biotic communities map developed by Reichenbacher et al. (1998) by adding political boundaries and several large rivers. Some of the larger biotic communities were then divided into recognizable subdivisions as had been done by Shreve (1951) for the Sonoran Desert, Braun (1967) and Greller (1988) for the Northeastern Deciduous Forest, Shelford (1963) and Sims (1988) for Plains Grassland, Moravka (1977) for the Chihuahuan Desert, and West (1988) for the Great Basin Desert. We also added Balcones Woodland as described and delineated by Blair (1950) for the Edwards Plateau region in Texas.

The choice of colors was carefully considered and follow the color scheme developed by Henri Gaüssen (1953, 1955), which was later adapted by Udvardy (1975) for the world's biogeographic regions. In this ecological classification system, arid habitats are represented by light colors, the shades becoming progressively darker in the wetter communities until the most mesic entities are represented by solid, dark colors. Cold habitats are denoted by cold, dull colors - grays, dark blues, and purples. As communities become progressively warmer, the colors representing them become brighter until the brilliant warm colors of the tropics - yellows, oranges, scarlets, and magentas are used to signify the formations depicted. As a general rule, tundra communities are depicted in shades of gray, temperate grasslands in various tones of brown, conifer forests by purples and blues, temperate forests and chaparral by combinations of blues and greens, thornscrubs and savannas as yellows and oranges, tropical deciduous forests in shades of red, and tropical evergreen forests in violets and magentas. Selecting the actual color to represent a biotic community, although complex and difficult due to number of communities involved, was greatly facilitated through the use of a color wheel (Process Color System Guide, Pantone) by which more than three-thousand color shades are arranged according to the percentage sequence of four basic colors (cyan, magenta, yellow, and black). ArcMap was used to assign each community cyan, magenta, yellow, and black (CMYK) color values. For publication purposes, we exported the ArcMap file as a new, encapsulated postscript (EPS) file. Overall, the color selected for each biotic community is, therefore, a combination of colors intended to illustrate moisture and temperature gradients, formation-class, and discernability on a continental scale.

BIOTIC COMMUNITIES OF ARIZONA

David E. Brown, Thomas C. Brennan, and Andrew T. Holycross



1,000 NEARCTIC REALM

1,111 ARCTIC AND ALPINE TUNDRAS
111.6 Rocky Mountain and Great Basin Alpine Tundra

121 BOREAL AND SUBALPINE FORESTS AND WOODLANDS
121.3 Rocky Mountain and Great Basin Subalpine Conifer Forest

122 COLD TEMPERATE FORESTS AND WOODLANDS
122.6 Rocky Mountain Montane Conifer Forest
122.7 Great Basin Conifer Woodland

123 WARM TEMPERATE FORESTS AND WOODLANDS
123.3 Madrean Evergreen Forest and Woodland

133 WARM TEMPERATE SCRUBLANDS
133.3 Southwestern (Arizona) Interior Chaparral

142 COLD TEMPERATE GRASSLANDS
142.12 Plains and 142.13 InterMountain Grassland

143 WARM TEMPERATE GRASSLANDS
143.1 Semidesert Grassland

152 COLD TEMPERATE DESERTLANDS
152.1 Great Basin Desertscrub

153 WARM TEMPERATE DESERTLANDS
153.1 Mohave Desertscrub
153.2 Chihuahuan Desertscrub

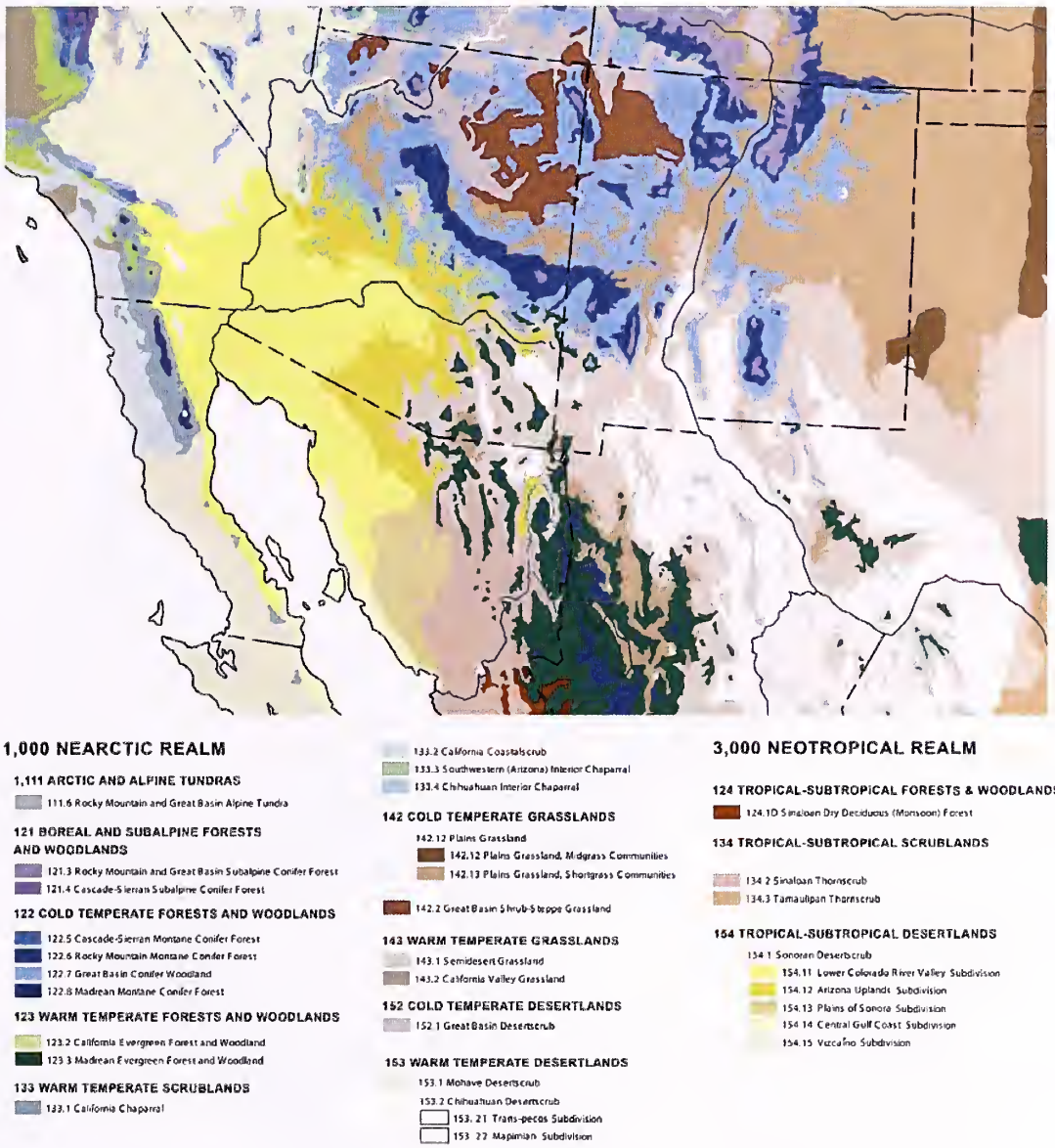
3,000 NEOTROPICAL REALM

154 TROPICAL-SUBTROPICAL DESERTLANDS
154.1 Sonoran Desertscrub
154.11 Lower Colorado River Valley Subdivision
154.12 Arizona Uplands Subdivision

Map and Legend Figure 1. Biotic Communities of Arizona.

BIOTIC COMMUNITIES OF THE SOUTHWESTERN UNITED STATES AND NORTHWESTERN MEXICO.

David E. Brown, Thomas C. Brennan, Charles H. Lowe, Jr., and Peter J. Unmack


1,000 NEARCTIC REALM
1,111 ARCTIC AND ALPINE TUNDRAS
111.6 Rocky Mountain and Great Basin Alpine Tundra
121 BOREAL AND SUBALPINE FORESTS AND WOODLANDS
121.3 Rocky Mountain and Great Basin Subalpine Conifer Forest
121.4 Cascade-Sierran Subalpine Conifer Forest
122 COLD TEMPERATE FORESTS AND WOODLANDS
122.5 Cascade-Sierran Montane Conifer Forest
122.6 Rocky Mountain Montane Conifer Forest
122.7 Great Basin Conifer Woodland
122.8 Madrean Montane Conifer Forest
123 WARM TEMPERATE FORESTS AND WOODLANDS
123.2 California Evergreen Forest and Woodland
123.3 Madrean Evergreen Forest and Woodland
133 WARM TEMPERATE SCRUBLANDS
133.1 California Chaparral
133.2 California Coastalscrub
133.3 Southwestern (Arizona) Interior Chaparral
133.4 Chihuahuan Interior Chaparral
142 COLD TEMPERATE GRASSLANDS
142.12 Plains Grassland
142.12 Plains Grassland, Midgrass Communities
142.13 Plains Grassland, Shortgrass Communities
142.2 Great Basin Shrub-Steppe Grassland
143 WARM TEMPERATE GRASSLANDS
143.1 Semidesert Grassland
143.2 California Valley Grassland
152 COLD TEMPERATE DESERTLANDS
152.1 Great Basin Desertscrub
153 WARM TEMPERATE DESERTLANDS
153.1 Mohave Desertscrub
153.2 Chihuahuan Desertscrub
153.21 Trans-pecos Subdivision
153.22 Mapimian Subdivision
3,000 NEOTROPICAL REALM
124 TROPICAL-SUBTROPICAL FORESTS & WOODLANDS
124.10 Sinaloan Dry Deciduous (Monsoon) Forest
134 TROPICAL-SUBTROPICAL SCRUBLANDS
134.2 Sinaloan Thornscrub
134.3 Tamaulipan Thornscrub
154 TROPICAL-SUBTROPICAL DESERTLANDS
154.1 Sonoran Desertscrub
154.11 Lower Colorado River Valley Subdivision
154.12 Arizona Uplands Subdivision
154.13 Plains of Sonora Subdivision
154.14 Central Gulf Coast Subdivision
154.15 Vizcaíno Subdivision

Map and Legend Figure 2. Biotic communities of the Southwestern United States and Northwestern Mexico.

BIOTIC COMMUNITIES OF NORTH AMERICA

David E. Brown, Thomas C.Brennan, Susan F. Franson, Frank W. Reichenbacher, and Peter J. Unmack

1,000 NEARCTIC REALM
1,111 ARCTIC AND ALPINE TUNDRAS
111.1 Polar (High Arctic) Tundra
111.2 Alaskan Tundra
111.3 Canadian (Low Arctic) Tundra
111.4 Greenlandian Coastal Tundra
111.5 Arctic Alpine Tundra
111.6 Rocky Mountain and Great Basin Alpine Tundra
111.7 Cascade-Sierran Alpine Tundra
111.8 Adirondack-Appalachian Alpine Tundra
111.9 Transvolcanic Alpine Tundra
121 BOREAL AND SUBALPINE FORESTS AND WOODLANDS
121.1 Alaska-Yukon Subarctic Conifer Forest
121.2 Canadian Taiga
121.3 Rocky Mountain and Great Basin Subalpine Conifer Forest
121.4 Cascade-Sierran Subalpine Conifer Forest
121.5 Adirondack-Appalachian Subalpine Conifer Forest
122 COLD TEMPERATE FORESTS AND WOODLANDS
122.1 Northeastern Deciduous Forest
122.11 Hemlock-White Pine and Northern Hardwood Regio
122.12 Mixed Mesophytic Region
122.13 Western Mesophytic Region
122.14 Oak and Chestnut Region
122.15 Beech and Maple Region
122.16 Maple and Basswood Region
122.17 Oak and Hickory Region
122.18 Oak-Pine Region
122.2 Sitka Coastal Conifer Forest
122.3 Oregonian Coastal Conifer Forest
122.4 Oregonian Deciduous and Evergreen Forests
122.5 Cascade-Sierran Montane Conifer Forest
122.6 Rocky Mountain Montane Conifer Forest
122.7 Great Basin Conifer Woodland
122.8 Madrean Montane Conifer Forest
122.9 Transvolcanic Montane Conifer Forest
122.1A Guatemalan Montane Conifer Forest
123 WARM TEMPERATE FORESTS AND WOODLANDS
123.1 Southeastern Deciduous and Evergreen Forests
123.12 Balcones Mixed Evergreen Woodland
123.2 California Evergreen Forest and Woodland
123.3 Madrean Evergreen Forest and Woodland
123.5 Transvolcanic Evergreen Foreast and Woodland
123.6 Guerreran Evergreen Forest and Woodland
123.7 Guatemalan Cloud Forest
123.8 Guatemalan Evergreen Forest and Woodland
123.9 Veracruz Cloud Forest
123.1A San Lucan Evergreen Forest and Woodland
132 COLD TEMPERATE SCRUBLANDS
132.1 Great Basin Montane Scrub
133 WARM TEMPERATE SCRUBLANDS
133.1 California Chaparral
133.2 California Coastalscrub
133.3 Southwestern (Arizona) Interior Chaparral
133.4 Chihuahuan Interior Chaparral
142 COLD TEMPERATE GRASSLANDS
142.12 Plains Grassland
142.12 Plains Grassland, Midgrass Communities
142.13 Plains Grassland, Shortgrass Communities
142.11 Plains Grassland, Tallgrass Communities
142.2 Great Basin Shrub-Steppe Grassland
143 WARM TEMPERATE GRASSLANDS
143.1 Semidesert Grassland
143.2 California Valley Grassland
143.3 Gulf Coastal Grassland
152 COLD TEMPERATE DESERTLANDS
152.1 Great Basin Desertscrub
153 WARM TEMPERATE DESERTLANDS
153.1 Mohave Desertscrub
153.2 Chihuahuan Desertscrub
153.21 Trans-pecos Subdivision
153.22 Mapimian Subdivision
153.23 Saldan Subdivision
160 NON-VEGETATED
160 Permanent Ice and Snow
1,200 NEARCTIC WETLANDS
200 Undifferentiated Nearctic Wetlands
223.1 Southeastern Swamp and Riparian Forest
231.3 Alaskan Swamp Scrub
3,000 NEOTROPICAL REALM
3,111 ALPINE PÁRAMOS
111.1 Central American Páramo
124 TROPICAL-SUBTROPICAL FORESTS & WOODLANDS
124.1 Central American Cloud Forest
124.2 Central American Evergreen Rain Forest
124.3 Central American Semi-evergreen Forest
124.4 Central American (Guanacaste) Dry Forest
124.5 Campechian Montane Evergreen Forest
124.6 Campechian Semi-evergreen Forest
124.7 Yucatan Semi-deciduous Forest
124.8 Yucatan Dry Deciduous Forest
124.9 Guerreran Dry Deciduous Forest
124.1A Veracruz Evergreen Rain Forest
124.1B Veracruz Semi-evergreen Forest
124.1C Nayarit-Guerreran Semi-evergreen Forest
124.1D Sinaloan Dry Deciduous (Monsoon) Forest
124.1E Tamaulipan Semi-deciduous Forest
124.1F San Lucan Dry Deciduous Forest
124.1G Caribbean Cloud and Montane Evergreen Forests
124.1H Caribbean Lowland Evergreen and Semi-evergreen Forests
124.1I Caribbean Dry Forest
124.1J Floridian Evergreen Forest
134 TROPICAL-SUBTROPICAL SCRUBLANDS
134.1 Guerreran Thornscrub
134.2 Sinaloan Thornscrub
134.3 Tamaulipan Thornscrub
134.4 San Lucan Thornscrub
134.5 Caribbean Thornscrub
144 TROPICAL-SUBTROPICAL GRASSLANDS
144.1 Central American Savanna Grassland
144.2 Guerreran Savanna Grassland
144.3 Campechian-Veracruz Savanna Grassland
144.4 Caribbean Savanna Grassland
154 TROPICAL-SUBTROPICAL DESERTLANDS
154.1 Sonoran Desertscrub
154.11 Lower Colorado River Valley Subdivision
154.12 Arizona Uplands Subdivision
154.13 Plains of Sonora Subdivision
154.14 Central Gulf Coast Subdivision
154.15 Vizcaíno Subdivision
200 NEOTROPICAL WETLANDS
200 Undifferentiated Neotropical Wetlands

Legend Figure 3. Digitized Biotic Community Map of North America.

Map Figure 4. Digitized Biotic Community Map of North America.

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